CDF

- CDF and the Tevatron
- B_s mixing, Rare Decays and New Mesons
- B-jet Production
- Top Mass and Higgs Search (talk by N. Austin)
- Supersymmetry
- Extra Dimensions (talk by S.-M. Wynne)

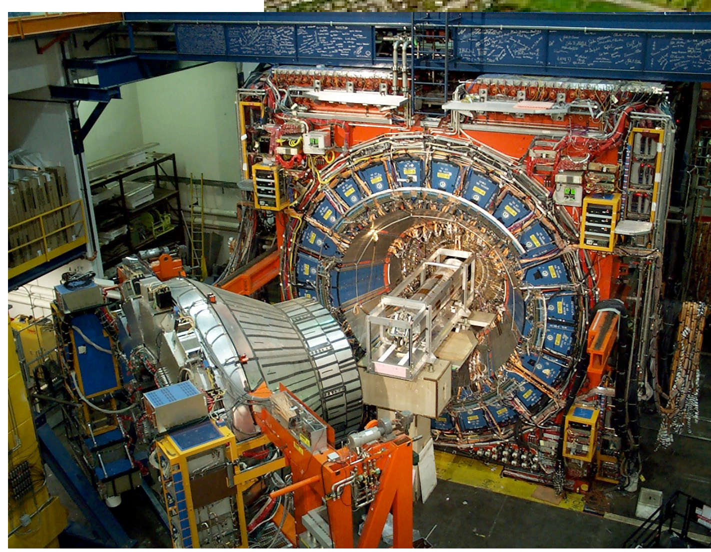
T. Berry, S. Farrington, B.H., M. Griffiths, M. Houlden, B. King, G. Manca, A. Mehta, R. McNulty, R. Oldeman, T. Shears, S. M. Wynne,
and Welcome to Nick Austin!

Beate Heinemann

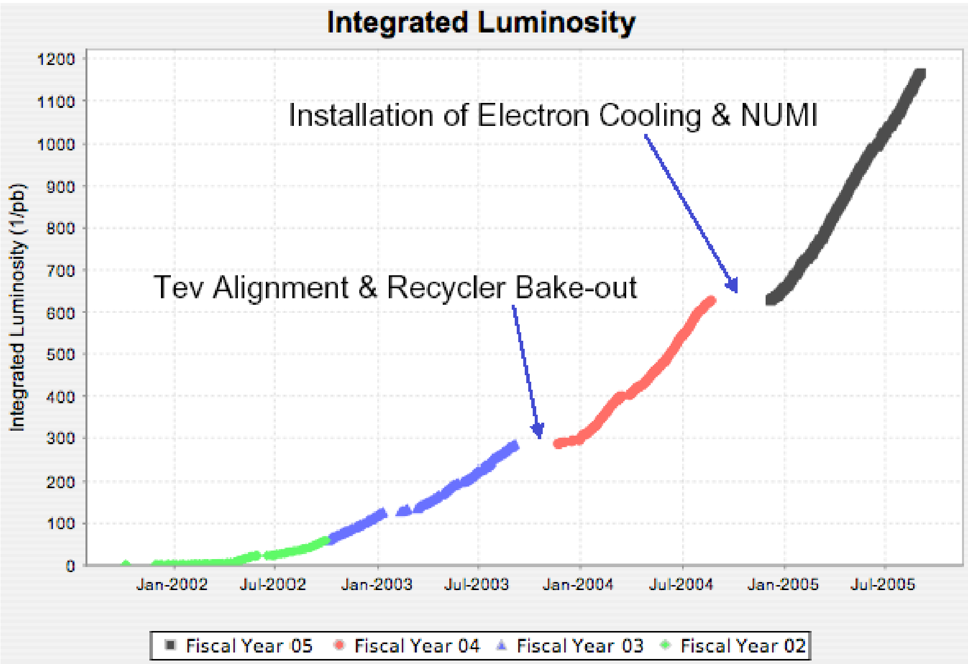
Liverpool Christmas Meeting, 20/12/2005

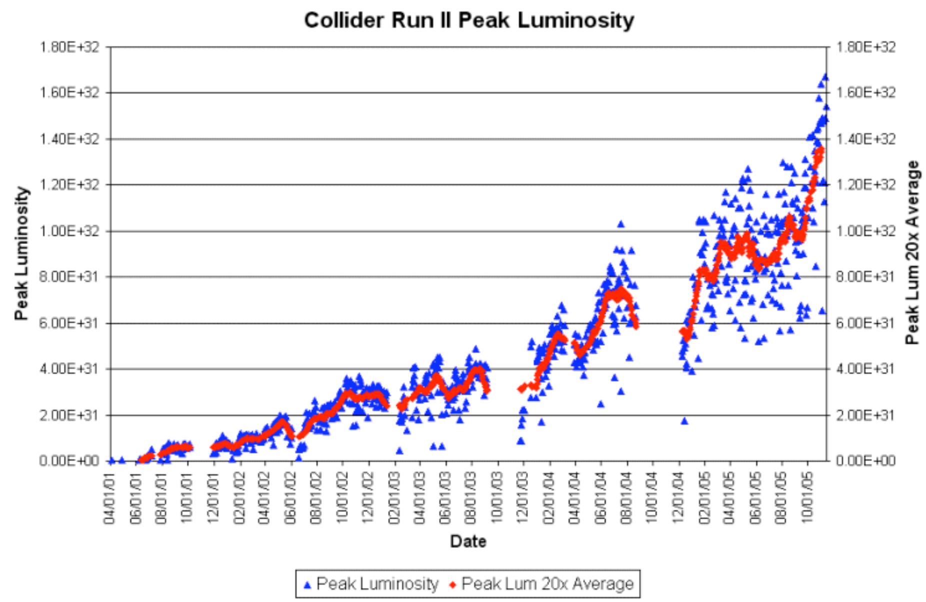
Tevatron Run II

- Accelerator:
  - Proton-anti-proton collisions
  - 4 miles circumference
  - Collisions happen every 396 ns
    - 2.5M collisions per second
  - Proton energy 980 GeV
    - World's highest energy collider
- CDF:
  - Calorimeters
  - Tracking drift chamber
  - Silicon vertexing and tracking:
    - Liverpool contributed to L00 (1.5cm from beam)
  - Muon detector systems



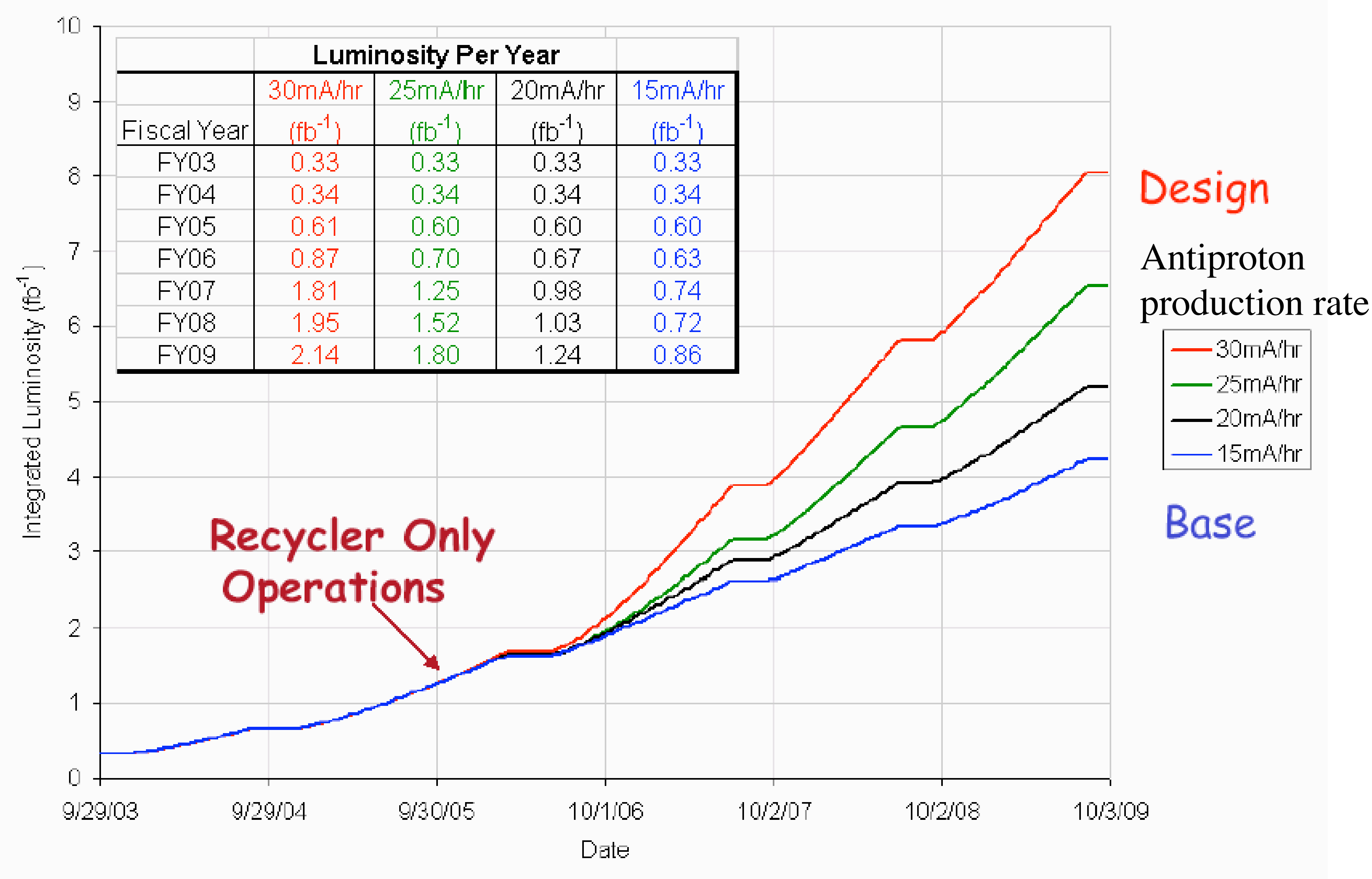
Accelerator did great this year!





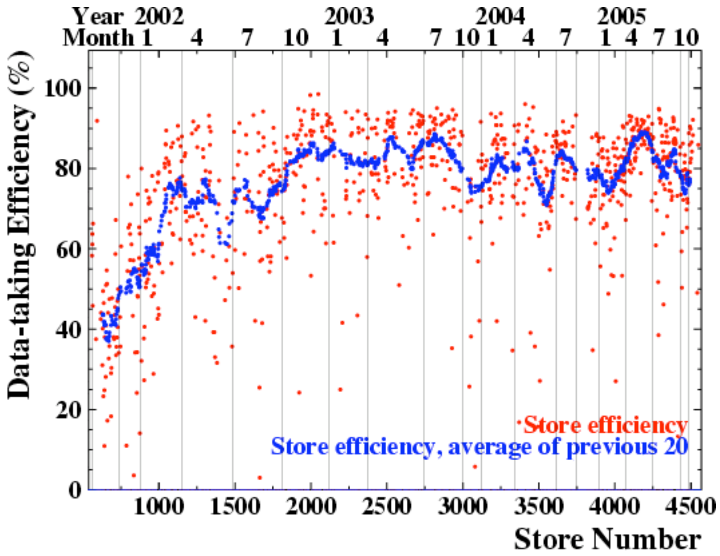
- Performance steadily improving: more than 1 fb^{-1} on tape
  - Recycler fully operational and being used
  - Electron cooling working
  - Instantaneous luminosity: 1.7×10^{32} cm^{-2} s^{-1}
    - Exceeded world record from ISR from 1983!
- remaining uncertainty: anti-proton production rate

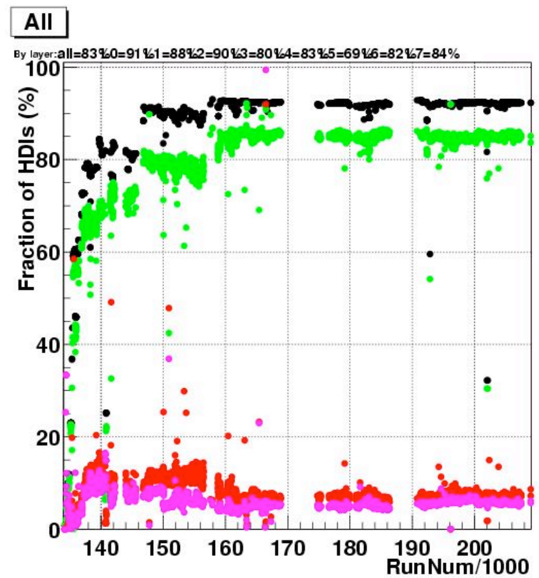
Luminosity: Future



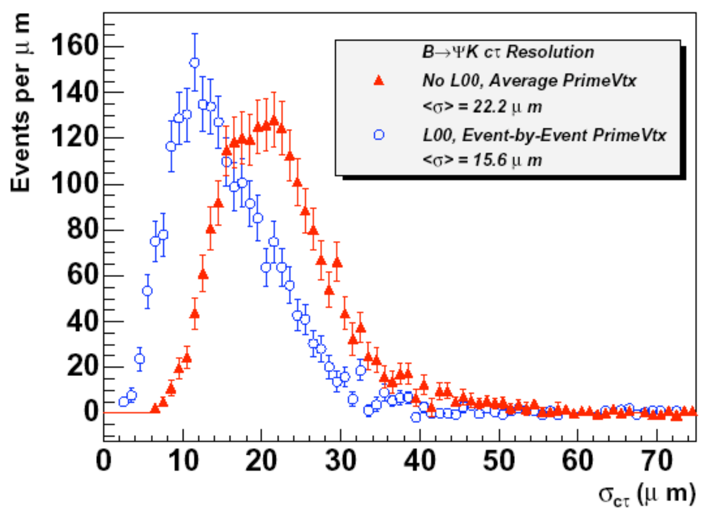
Fiscal Year	30mA/hr (fb^{-1})	25mA/hr (fb^{-1})	20mA/hr (fb^{-1})	15mA/hr (fb^{-1})
FY03	0.33	0.33	0.33	0.33
FY04	0.34	0.34	0.34	0.34
FY05	0.61	0.60	0.60	0.60
FY06	0.87	0.70	0.67	0.63
FY07	1.81	1.25	0.98	0.74
FY08	1.95	1.52	1.03	0.72
FY09	2.14	1.80	1.24	0.86

CDF Performance

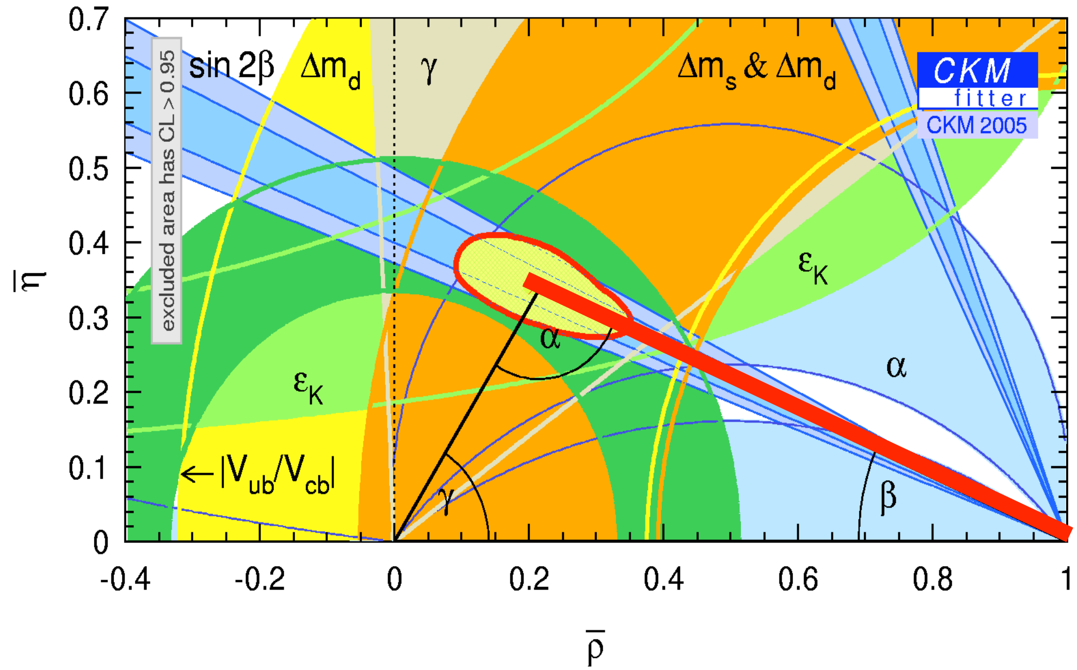


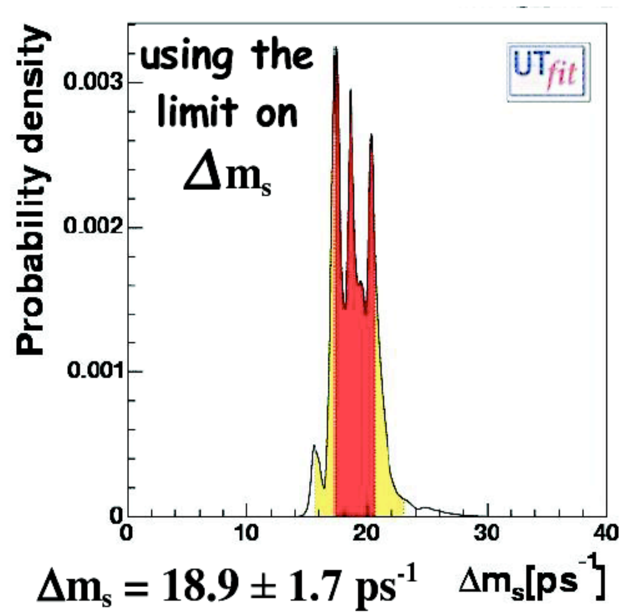


Efficiencies:
- Data Taking ~83%
- Silicon:
  - 96% powered
  - 85% good (1% error rate)
- Vertex resolution 15.6 μm:
  - thanks to Layer00



B_s^0- $\overline{B}_s^0$ mixing: Motivation



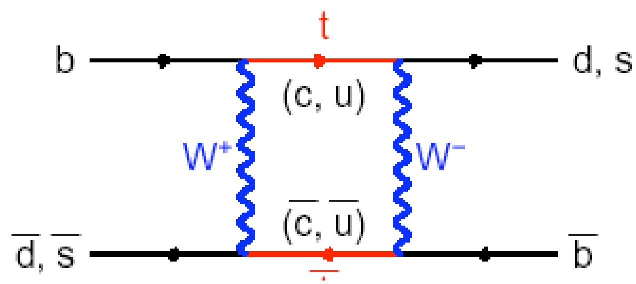


- Measure side of unitarity triangle:

  $\Delta m_d/\Delta m_s$

  – CKM fit: Δm_s =18.9±1.7 ps^{-1}

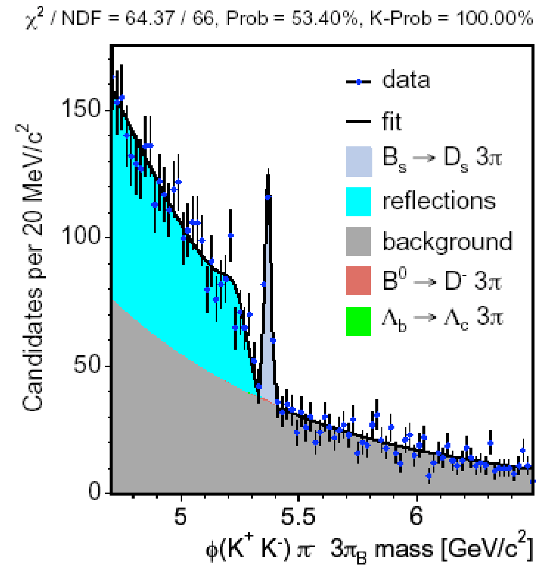
  – Observation will significantly shrink allowed region



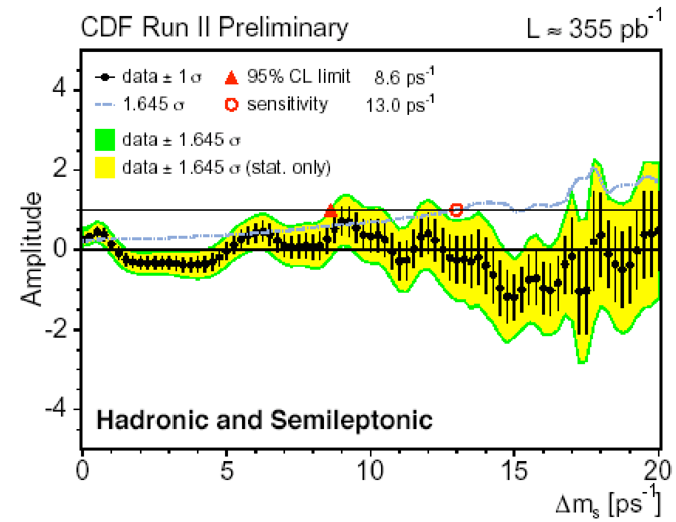
B_s^0- $\overline{B}_s^0$ mixing

S. Farrington, R. Oldeman

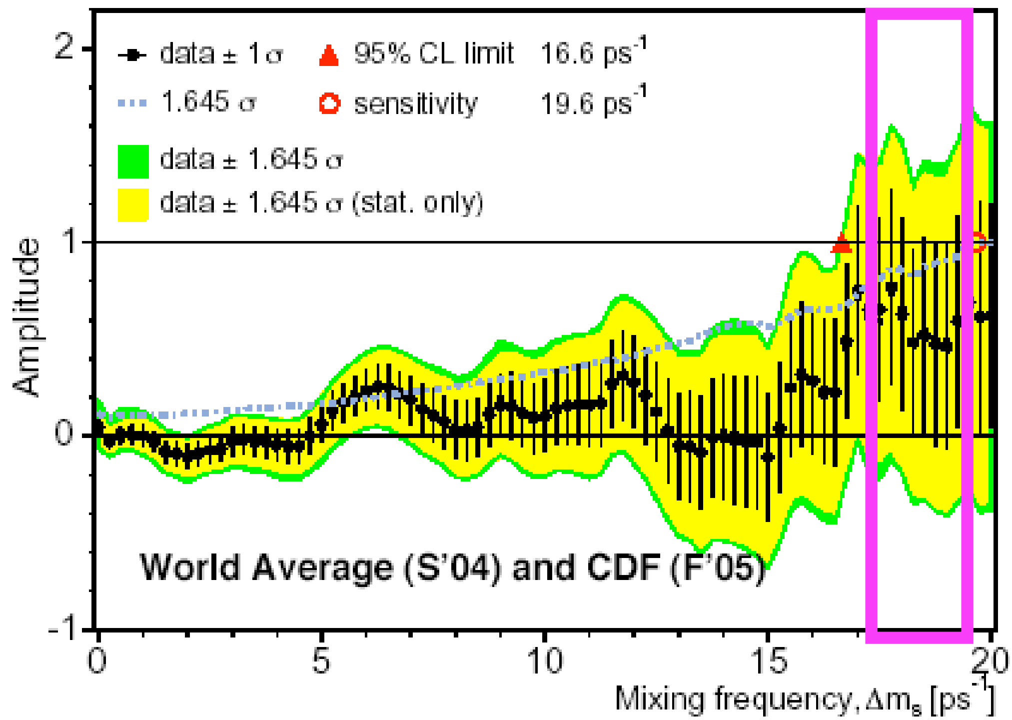
- Measurement relies on:
  - Good vertex resolution (Layer00)
  - Reconstruction of B_s decay modes
  - Flavour of b at production: εD^2
- Latest CDF result:
  - Observed: Δm_s>8.6 ps^{-1}
  - Sensitivity: Δm_s>13.0 ps^{-1}
- Single best experiment:
  - Along with ALEPH



$B_s \to D_s 3\pi, D_s \to \phi\pi$



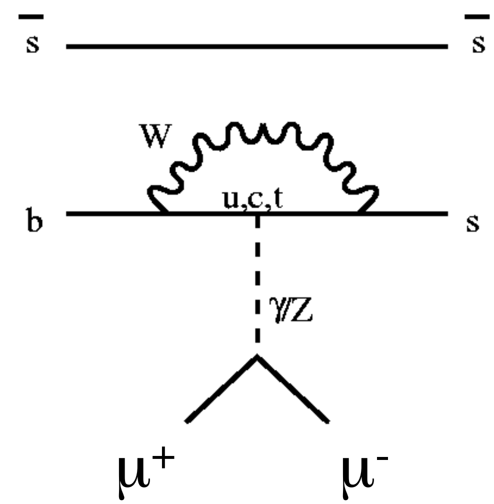
B_s^0- $\overline{B}_s^0$ mixing: World Result



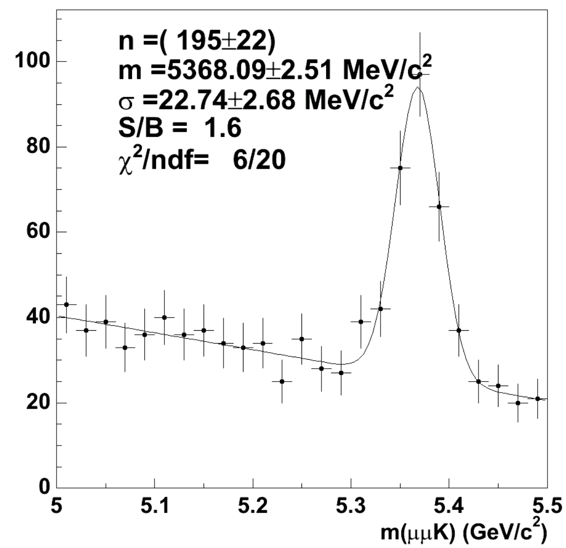
- World Data Combination:
  - Limit: $\Delta m_s > 16.6\ ps^{-1}$
  - Sensitivity: $\Delta m_s > 19.6\ ps^{-1}$
- Starting to be sensitive to SM value: **$18.9 +/- 1.7\ ps^{-1}$**

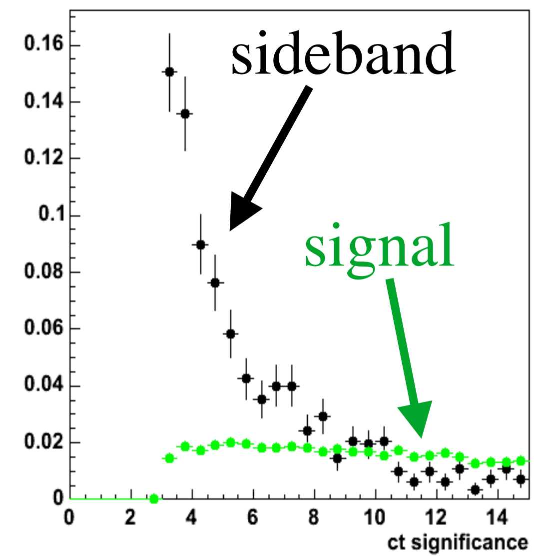
Search for FCNC

- FCNC processes can be enhanced BSM:
  - E.g. $b \rightarrow s\gamma^*$
- Search for:
  - $B^+ \rightarrow \mu\mu K^+$ (observed at Belle/BaBar)
  - $B \rightarrow \mu\mu K^*$ (observed at Belle/BaBar)
  - $B_s \rightarrow \mu\mu \phi$
    - predicted BR($B_s \rightarrow \mu\mu \phi$)=$16.1 \times 10^{-7}$



- Analysis blind:
  - Control modes analysed:
    - $B+ \rightarrow J/\psi K^+ \rightarrow \mu\mu K^+$
    - $B+ \rightarrow J/\psi K^* \rightarrow \mu\mu K^*$
    - $B+ \rightarrow J/\psi\ \phi \rightarrow \mu\mu\ \phi$
  - Cut optimisation ongoing



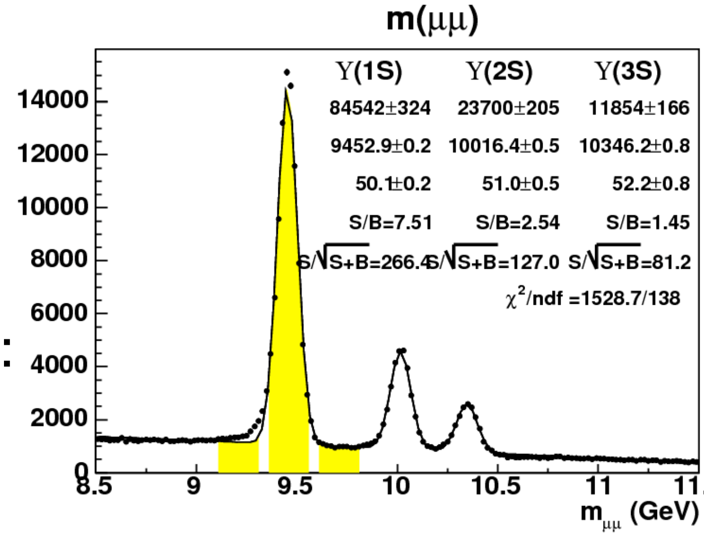


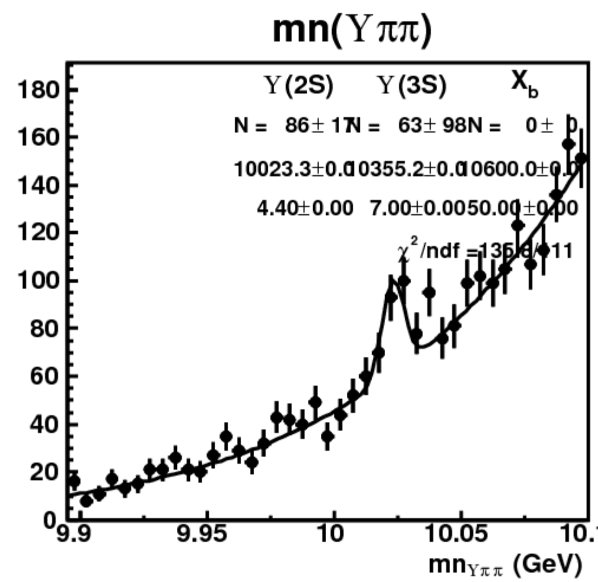
- Hoping for 3σ evidence for BR($B_s \rightarrow \mu\mu\ \phi$) with luminosity of 1 fb^{-1}

Search for $X_b \rightarrow \Upsilon(1S)\pi^+\pi^-$

S. Hewitt, R. Oldeman

- In 2003 Belle, CDF, D0, Babar discovered:
  - $X(3872) \rightarrow J/\psi\ \pi^+\pi^-$
  - Lot's of activity on understanding its nature:
    - 100+ citations for CDF paper alone
- Anologous $X_b \rightarrow \Upsilon(1S)\pi^+\pi^-$ predicted at 10.4-10.8 GeV
  - Reference signal $\Upsilon(2S) \rightarrow \Upsilon(1S)\pi^+\pi^-$
  - 85K upsilons in 860 pb^{-1} of data
  - Reference signal: 86 +/- 17 events
- 5σ sensitivity if $\approx 5\%$ of Υ come from $X_b \rightarrow \Upsilon(1S)\pi^+\pi^-$
  - Unknown *a priori*
  - Will open "blind box" soon

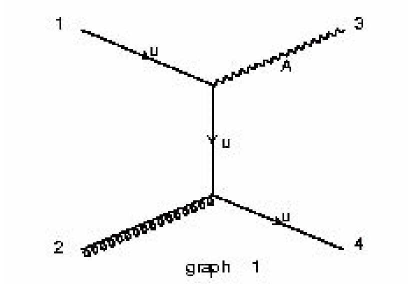


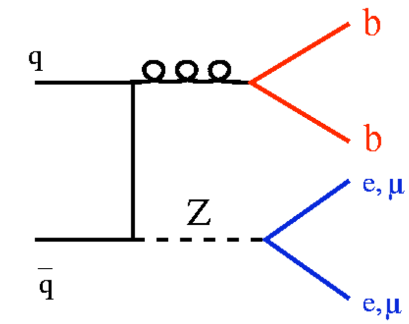


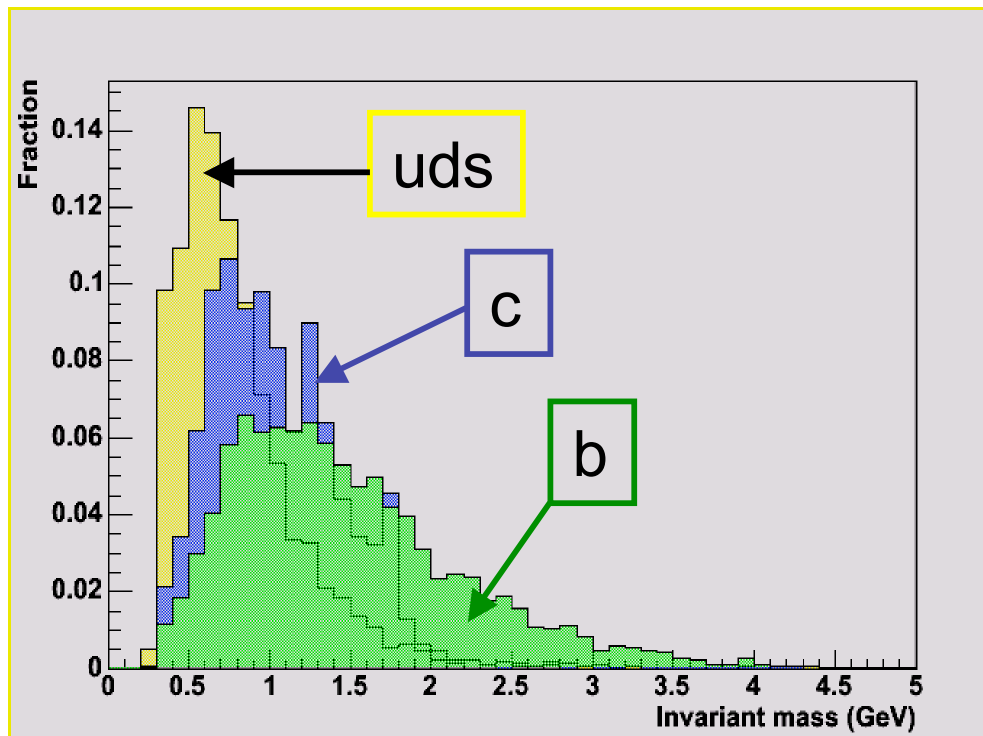
B-jet Production

- Many measurements:
  - Bbbar (Anant Gajjar)
  - Photon+b (T. Shears, R. McNulty)
  - Z+b (A. Mehta, B.H.)
- Interesting subject:
  - Test of QCD
  - Sensitive to Higgs (ZH and WH)
  - Sensitive to New Physics (γb: GMSB SUSY, Technicolor)
- Experimental Technique:
  - Fit mass at secondary vertex
  - Extract fraction of b-jets

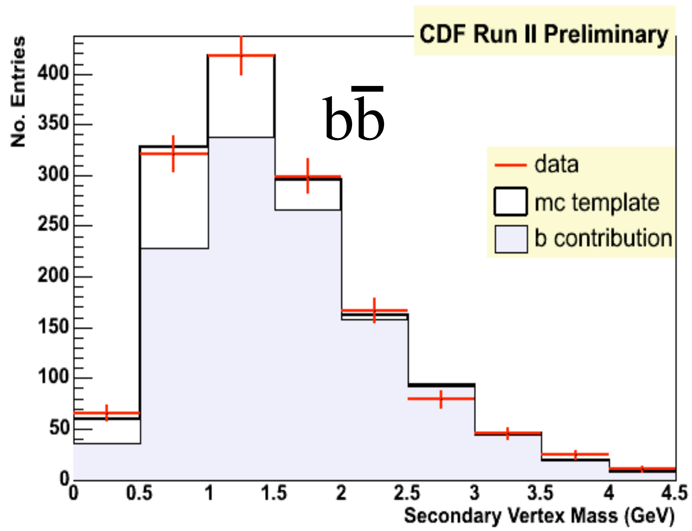
A. Gajjar, A. Mehta, R. McNulty, T. Shears

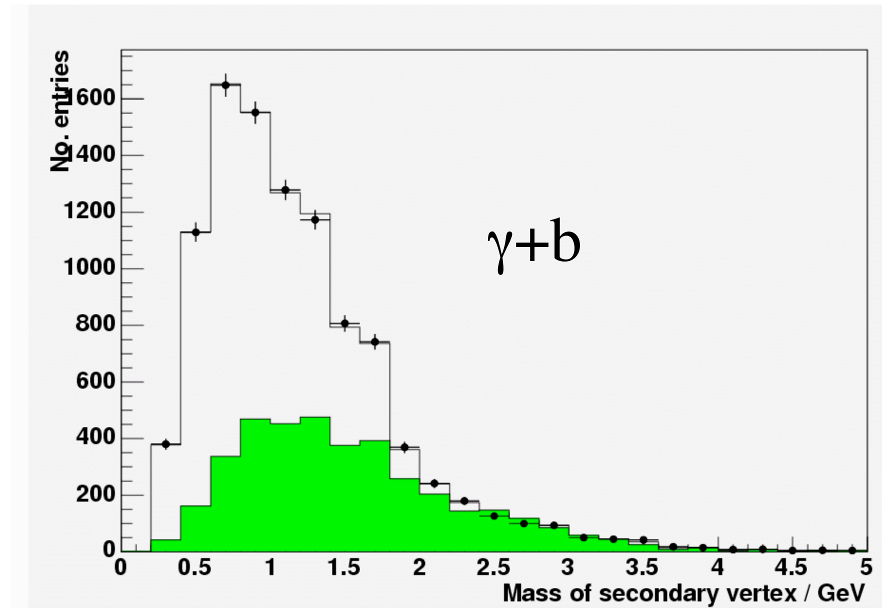


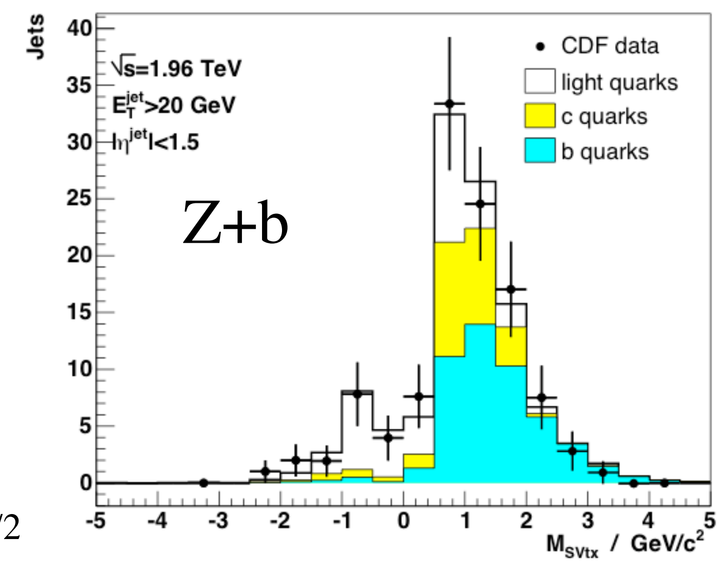




Fits to Vertex Mass





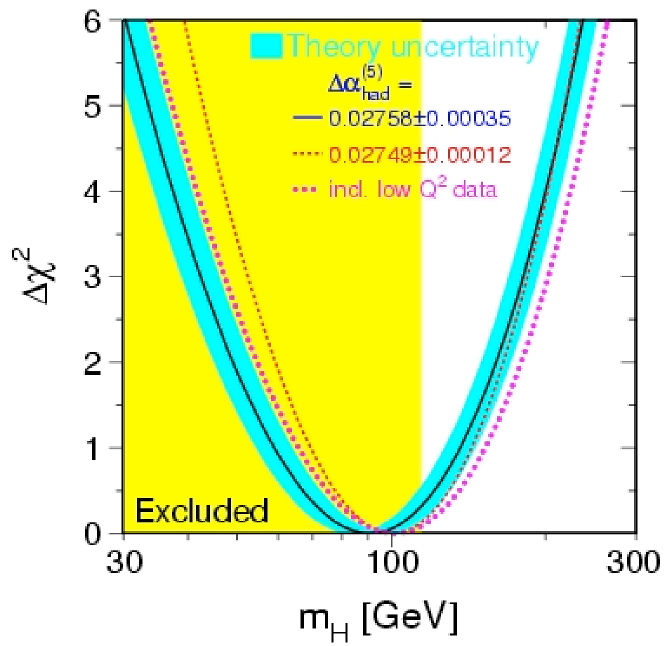


- Measured cross sections of all
- All three processes generally good agreement with theory predictions

A. Gajjar, A. Mehta, R. McNulty, T. Shears

W, top and Higgs

- W mass, top mass and Higgs mass related via loop corrections
- Precise knowledge of m_W and m_{top} allows us to constrain SM Higgs boson mass:
  - Run I Average: m_{top}=178.0+-4.3 GeV
    - m_H<280 GeV at 95%C.L.
  - New prel. Average: m_{top}=172.7+-2.9 GeV
    - m_H<186 GeV at 95%C.L.
- Very sensitive:
  - 4 GeV top mass shift
  - => 94 GeV shift in Higgs mass limit
- NB:
  - D0 shifted by ~7 GeV compared to Run 1
  - CDF agrees with Run 1 number within 1σ

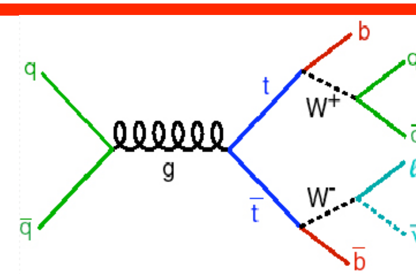


$M_{Higgs} = 91^{+45}_{-32}$ GeV

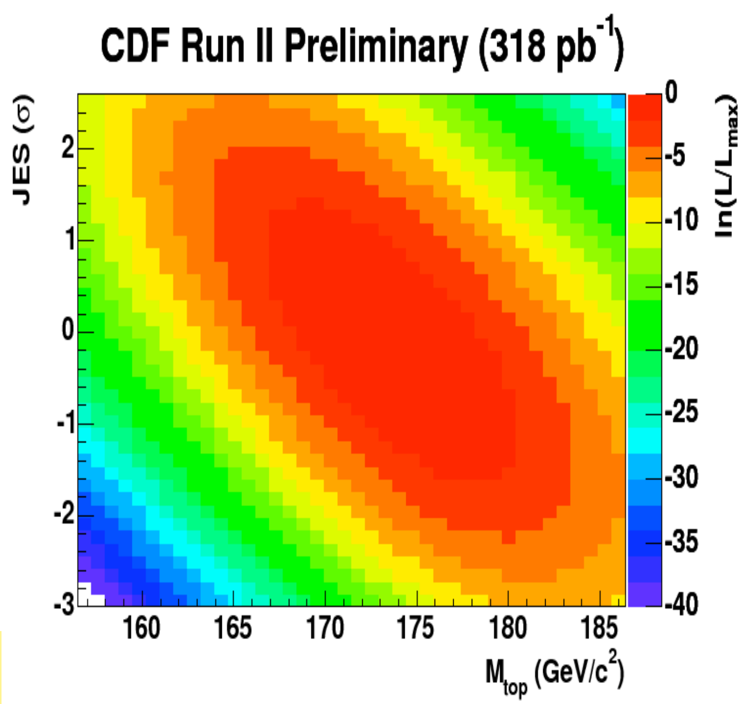
Top Quark Mass

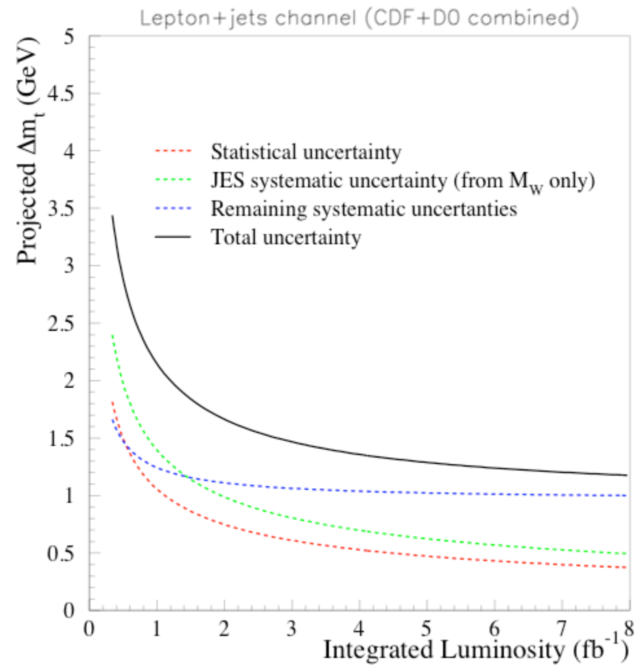
- Using W mass to determine jet energy scale of jets from W decay:

$$m_{top} = 173.5^{+2.7}_{-2.6}\,(stat.) \pm 2.5(JES) \pm 1.7\ (syst.)\ \mathrm{GeV/c^2}$$



- Jet Energy Scale is thus statistical problem
  - Uncertainty will decrease with √Lumi





2 fb^{-1}:Δm(top)< ±1.7 GeV /c^2

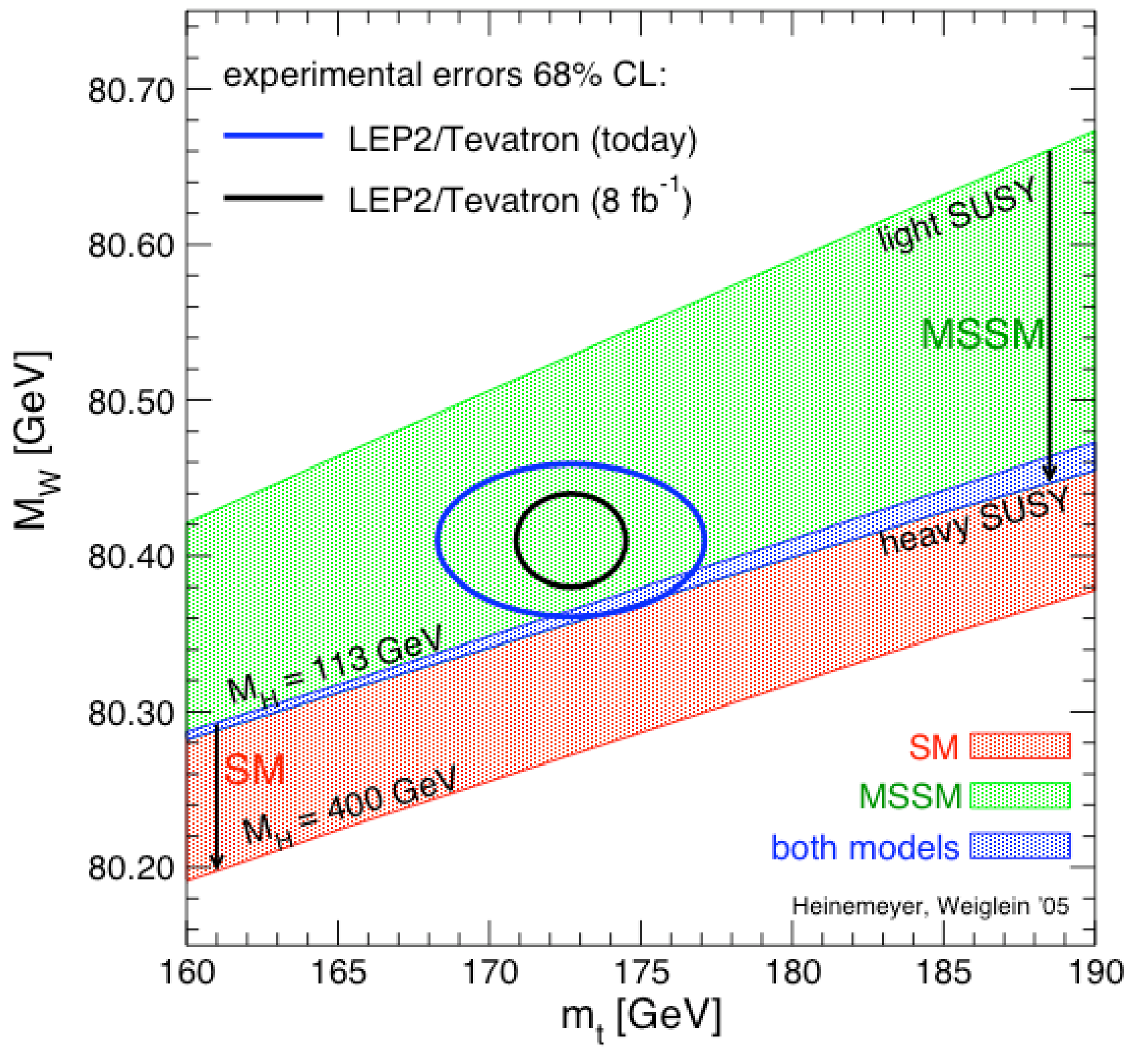
B. H.

NIM paper on jet energy scale: hep-ex/0510047

Implications for Higgs and SUSY

New preliminary top mass (D0+CDF): 172.7±2.9 GeV

- **Present:**
  - **Δm_{top} = 2.9 GeV**
  - **Δm_W = 34 MeV**
- **Future:**
  - **Δm_{top} = 1.2 GeV**
  - **Δm_W = 20 MeV**



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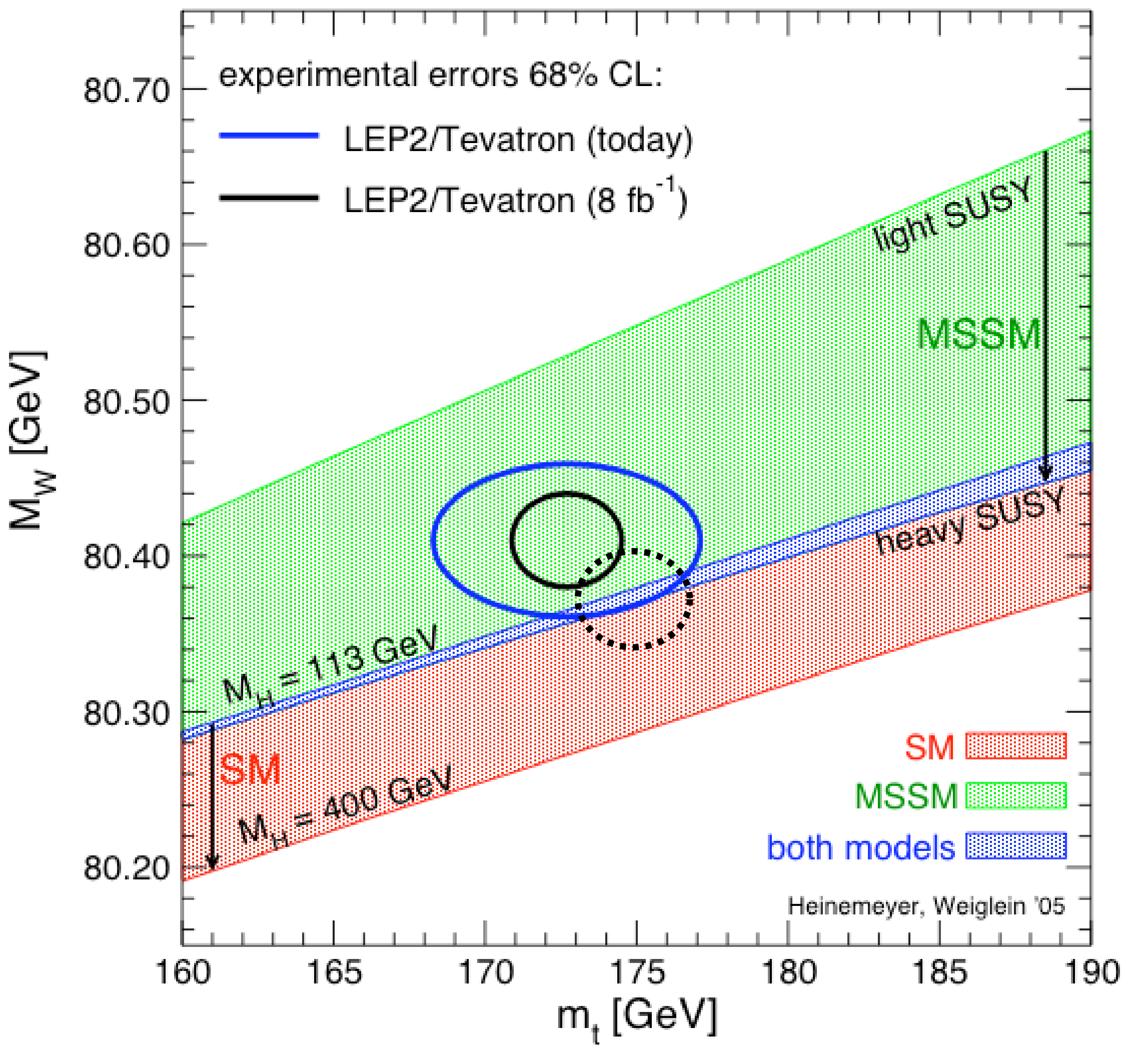

Can the Standard Model work?

Implications for Higgs and SUSY

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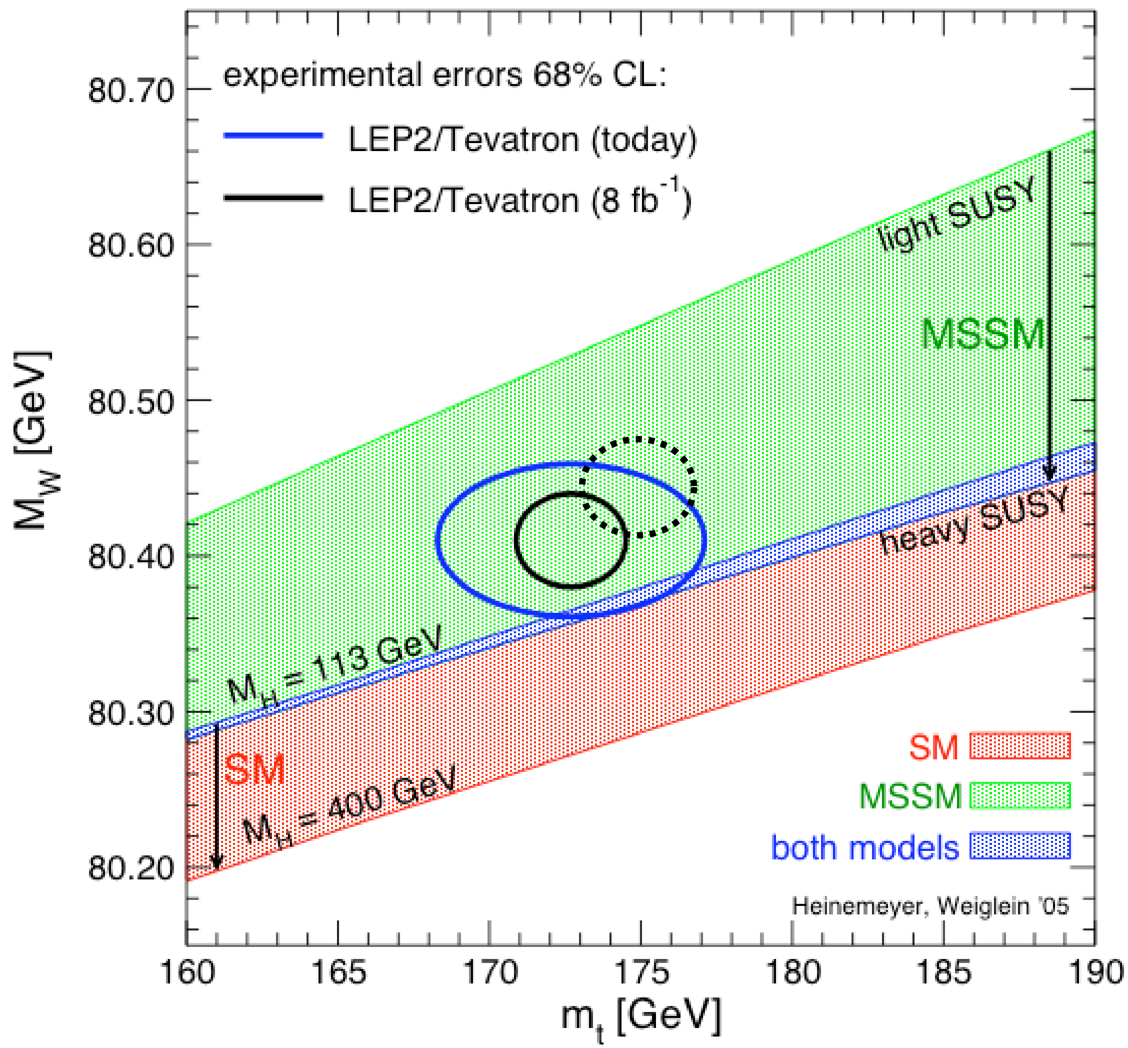
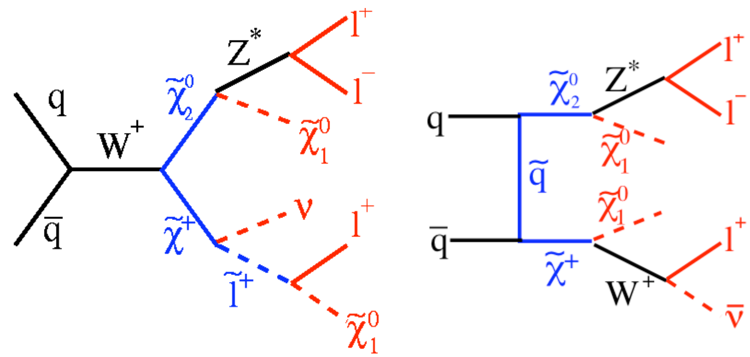


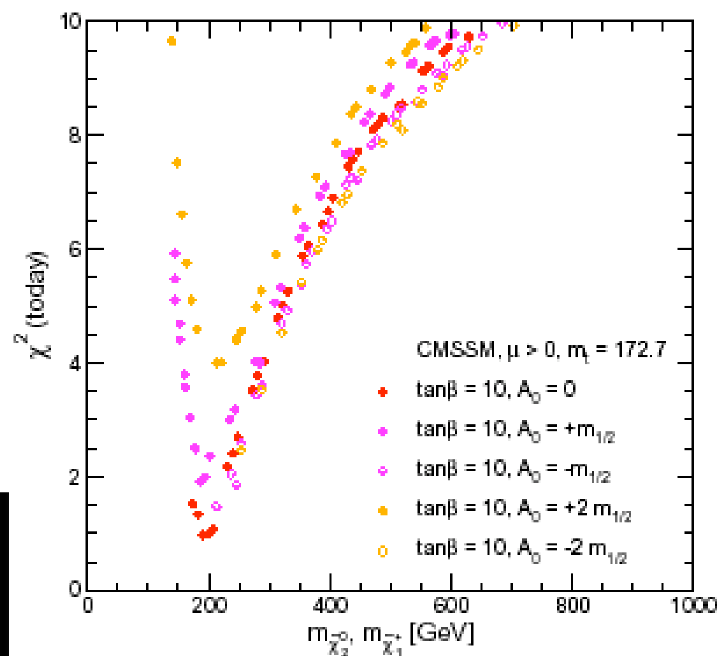
Or is Nature supersymmetric?

SUSY Trileptons

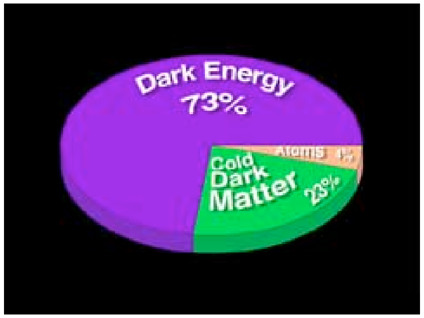
M. Griffith, G. Manca, BH

- "Golden" Trilepton Signature
  - Chargino-neutralino production
  - Low SM backgrounds
- 3 leptons and large Missing E_T:
  - Neutralino $\chi^0{}_1$ is LSP
- Recent analysis of electroweak precision and WMAP data (J. Ellis, S. Heinemeyer, K. Olive, G. Weiglein: hep-ph/0411216)
  - Preference for "light SUSY"
  - Chargino mass around 200 GeV/c^2
- Analysis from Martin and Giulia:
  - 3 l (l=e,μ)
  - $\not{E}_t$ +topological cuts
  - Analysis most sensitive at low tanβ
  - BG expectation: 0.6±0.08 events
  - Observed: 0 events



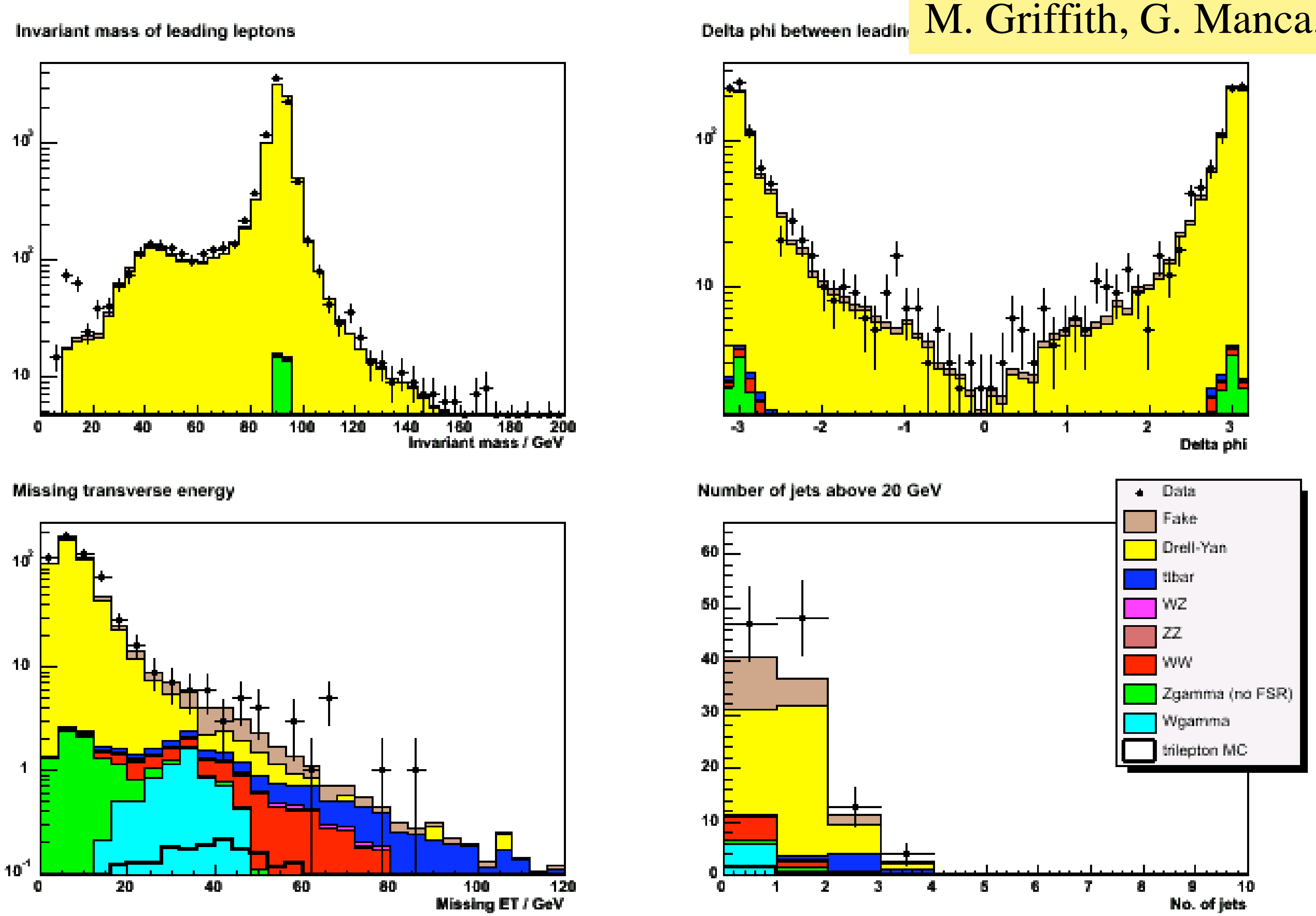


M(chargino)



SUSY Trileptons

M. Griffith, G. Manca, BH

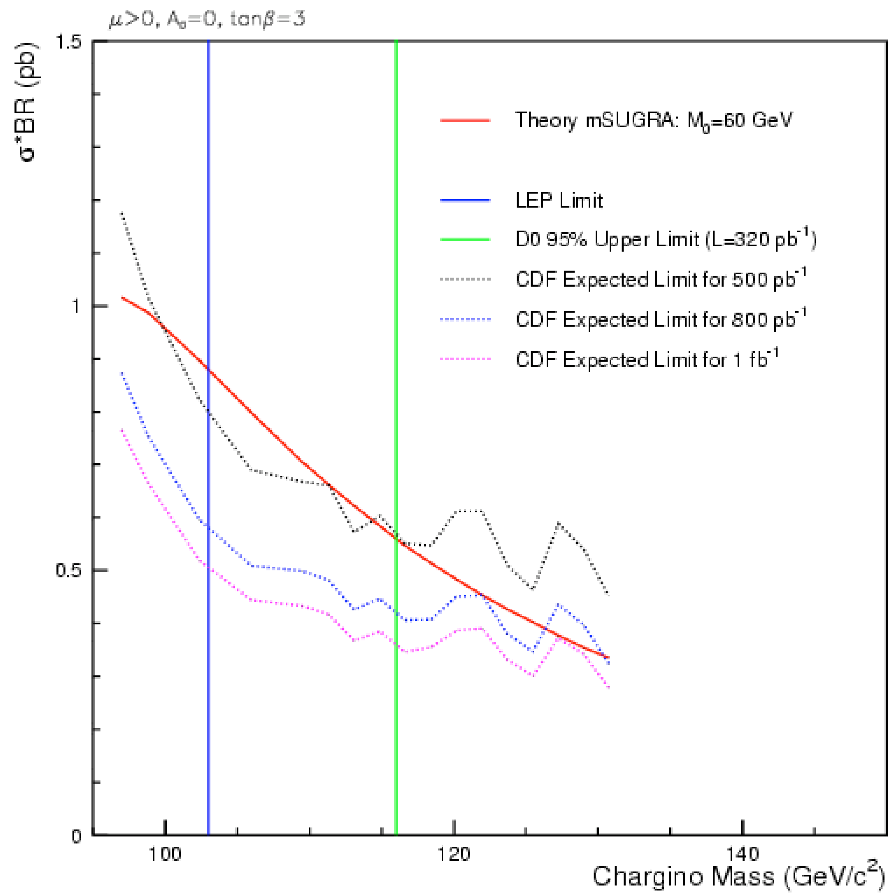


Good understanding of Backgrounds

Next Steps and Limiis

M. Griffith, G. Manca, BH

- Include 2005 data in analysis:
  - Double data sample: 800 pb^{-1}
- Combine with other analyses to maximise sensitivity
- Sensitive to charginos up to 130 GeV!



Conclusions and Outlook

- Tevatron and CDF performing very well
  - Will double luminosity in 2006 and then again in 2007
- Liverpool Group involved in important analyses:
  - Bs mixing and rare decays:
    - Good chance to observe B_s mixing and $B_s \rightarrow \phi\mu\mu$ decay this year!
    - Layer00 used by default and performs well
  - Probing QCD:
    - Nearly complete picture of b-jet production
    - So far good agreement with NLO QCD
  - New Physics: SUSY, Higgs (N. Austin), LED (S.M. Wynne)
    - Chance to discover or see evidence before the LHC
      - Should be able to beat LEP limit with 2 fb^{-1}
    - So far no hint of excess
- CDF will analyse ~1fb^{-1} by Summer '06

B_s mixing: Future Discovery

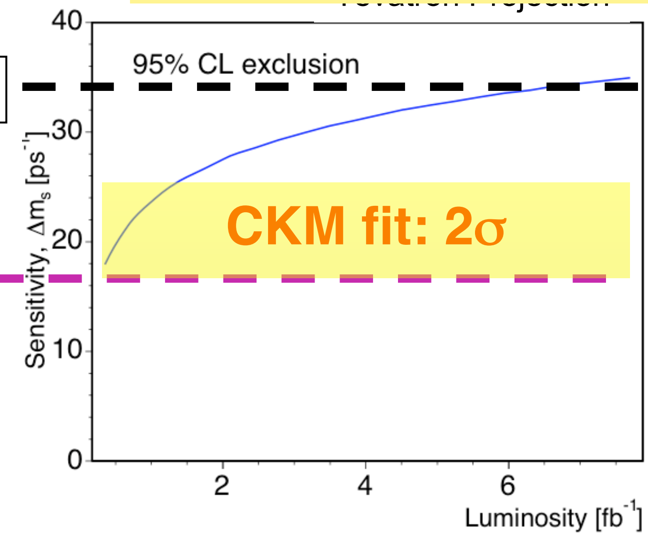
- CDF assume:
  - Flavour tagging:
    - Add same-side kaon tagger
    - εD^2=1.6% + 3%
  - Vertex resolution:
    - Improve by 10%
  - Trigger bandwidth:
    - Utilize 50% of CDF data

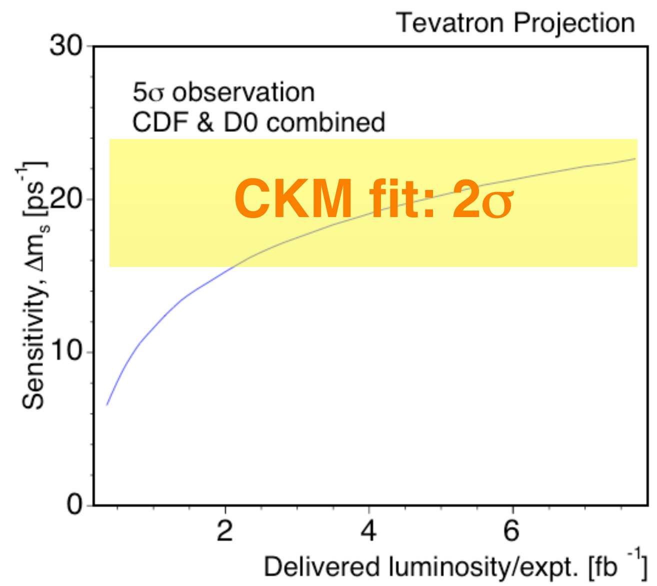
5σ Observation:
L=2 fb^{-1}: Δm_s<15 ps^{-1}
L=8 fb^{-1}: Δm_s<22 ps^{-1}

S. Farrington, R. Oldeman

New physics at 3σ

Current World Limit





By winter 2006 will have same-side kaon tagger and twice the data: could see a 3σ signal then!

Tevatron Luminosity

Congratulations Fermilab!

Fermilab has set a world record for peak luminosity of a hadron collider! Operations established store 4431 at 9:11 a.m. yesterday, October 4, with an initial luminosity, or brightness, of 141E30 $cm^{-2}sec^{-1}$. This record exceeds the previous Tevatron record by almost 8 percent, and it exceeds the world record for peak luminosity of a hadron collider achieved 23 years ago by the ISR proton-proton collider at CERN. The ISR achieved a peak luminosity of 140E30 $cm^{-2}sec^{-1}$ at a collision energy of 62 GeV. The Tevatron produces collisions between protons and antiprotons at a collision energy of 1960 GeV. The peak luminosity of the Tevatron has greatly increased since Fermilab began Run II in March 2001, and Fermilab expects to improve the Tevatron peak luminosity even further.

Again, Tevatron Sets World Record for Peak Luminosity

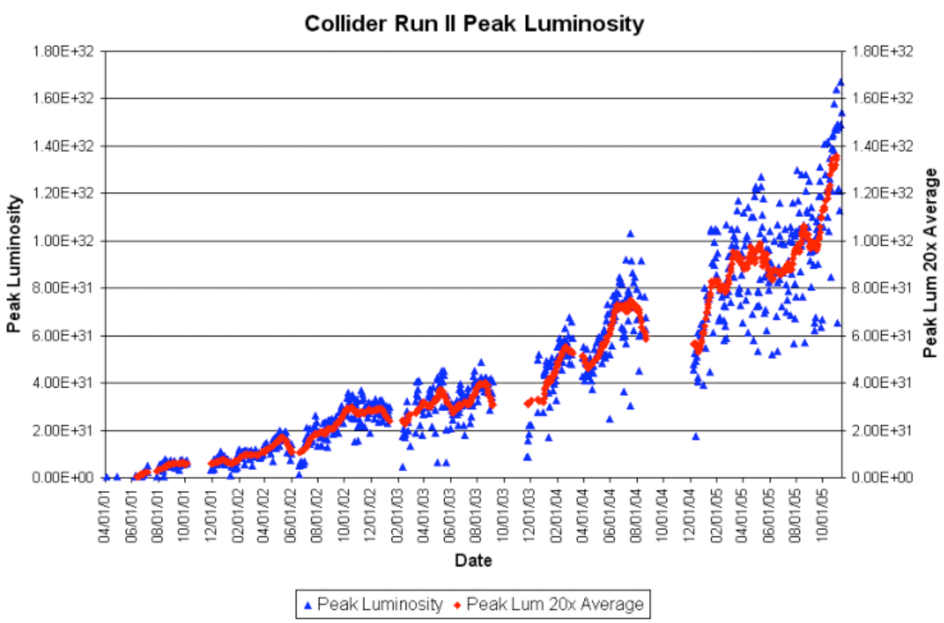
On Tuesday, October 25, at 3:28 a.m. the Tevatron improved its world-record peak luminosity to 144.91E30 $cm^{-2}sec^{-1}$. Significant contributions came from the new electron cooling system, which will be featured in an upcoming luminosity series in *Fermilab Today*. Congratulations!

Fermilab Sets Another World Record for Luminosity!

The Tevatron recently made a vast improvement in peak luminosity. Operators set a new record on Thursday, October 27 at 2:54 a.m. The new record of 158E30 $cm^{-2}sec^{-1}$ is almost 10 percent larger than the last record of 145E30 $cm^{-2}sec^{-1}$.

Records Keep Coming

The flurry of Tevatron peak luminosity records of the last couple of months continues. On Monday, October 31, accelerator operators produced a special Halloween treat of 164E30 $cm^{-2}sec^{-1}$. Since the beginning of the year, the peak luminosity record has increased by about 50 percent. Congratulations.

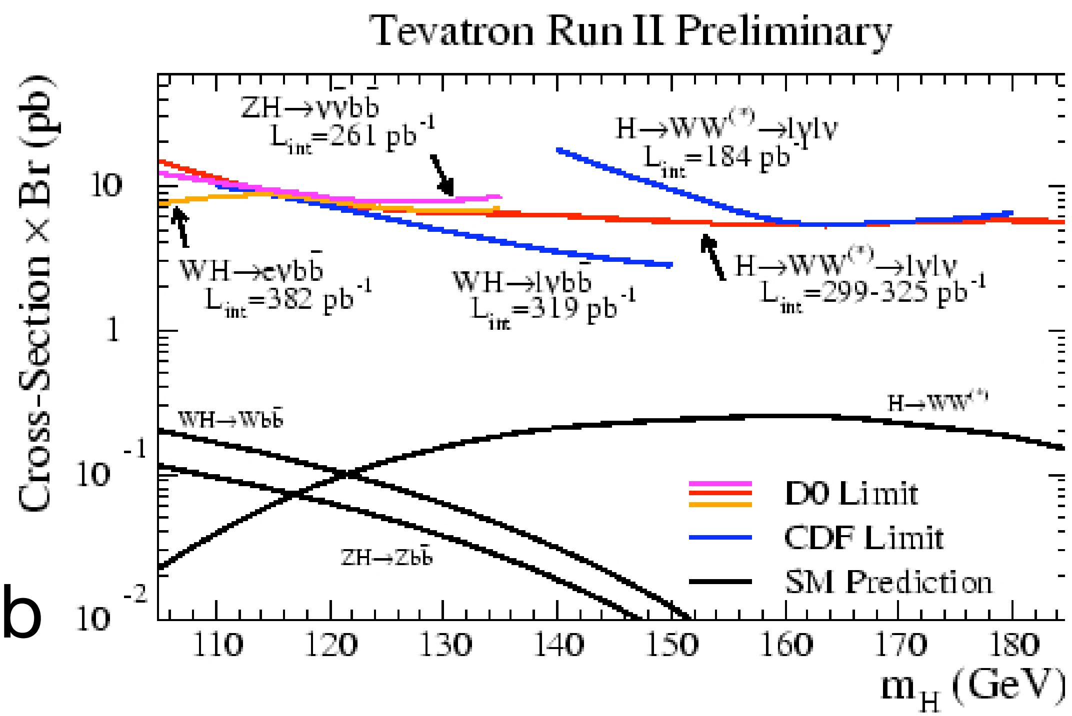


A New Record Every Week for Tevatron Luminosity

Last week, Fermilab once again set new world records for peak and integrated luminosity. At 8:00 p.m. on November 10, the peak luminosity reached 167E30$cm^{-2}sec^{-1}$. Even better, Fermilab surpassed its recent integrated luminosity record of 21 inverse picobarns as well. Between Monday, November 7 and Monday, November 14, the Tevatron's weekly integrated luminosity rose to 23 inverse picobarns, a record for the second straight week.

Current Higgs Search Results

- Results:
  - WH->lνbb
  - ZH-> ννbb
  - WW->llνν
  - WWW->l±l± + X
  - No result on ZH->llbb yet => Nick's thesis
- Cross section limits about 20 times larger than SM prediction



N. Austin, B. H., A. Mehta

Can we close the Gap?

- Assume current analyses as starting point
- Reevaluated all improvements using latest knowledge

	Luminosity equivalent=$(S/\sqrt{B})^2$		
Improvement	WH->lvbb	ZH->vvbb	ZH->llbb
mass resolution	1.7	1.7	1.7
Continuous b-tag (NN)	1.5	1.5	1.5
Forward b-tag	1.1	1.1	1.1
Forward leptons	1.3	1.0	1.6
Track-only leptons	1.4	1.0	1.6
NN selection	1.75	1.75	1.0
WH signal in ZH	1.0	2.7	1.0
Product of above	8.9	13.3	7.2
CDF+DØ combination	2.0	2.0	2.0
All combined	17.8	26.6	14.4

What Liverpool is working on

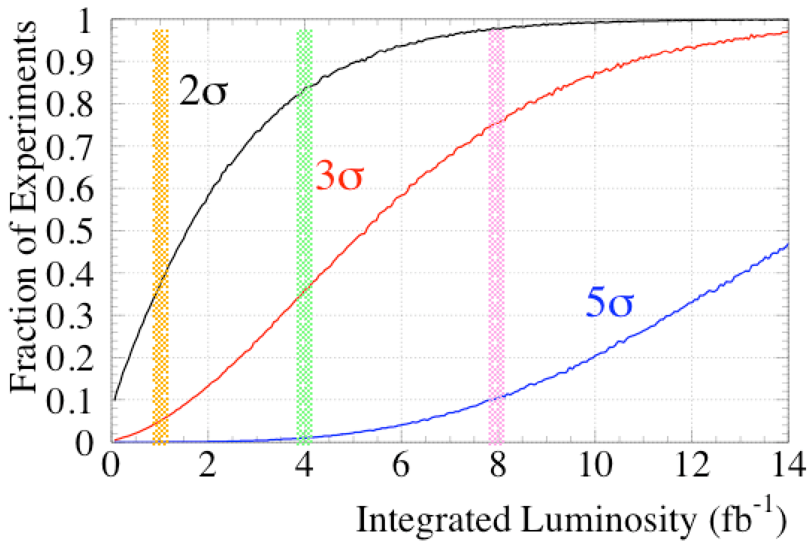
Expect factor ~10 improvements and CDF+DØ combination:

=> Of course not easy but looks feasible

“God Does Not Play Dice” ?

- Could get statistically lucky or unlucky (m_H=115 GeV/c^2):
  - with L=1 fb^{-1}:
    - 35% chance to improve LEP limit
    - 5% chance for 3σ evidence
  - with L=4 fb^{-1}:
    - >80% chanve to improve LEP limit
    - 35% chance for 3σ evidence
  - with L=8 fb^{-1}:
    - 75% chance for 3σ evidence

m_H=115 GeV/c^2



Supersymmetry

- Addresses many questions and problems in SM:
  - Elegant solution to hierarchy problem ($m_W << m_{Pl}$)
  - Achieves unification of gauge theories at GUT scale
  - Predicts a natural candidate for cold dark matter
    - if R-parity is conserved
- More than 100 parameters:
  - Rich phenomenology => many different signatures
- Experimental status:
  - No evidence found:
    - Stringent direct limits on sleptons and gauginos set by LEP:
      - e.g. $m(\chi^{\pm}) > 103.5$ GeV/c^2
  - Consistent with measurements of $\Omega_{DM}h^2$, $(g-2)_\mu$, $b \rightarrow s\gamma$ and electroweak precision data

(see seminar by Giulia Manca last week)